CHAPTER 8

MEASUREMENT AND PRESSURE CONTROL DEVICES

For safe and efficient operation, fluid power systems are designed to operate at a specific pressure and/or temperature, or within a pressure and/or temperature range.

You have learned that the lubricating power of hydraulic fluids varies with temperature and that excessively high temperatures reduce the life of hydraulic fluids. Additionally, you have learned that the materials, dimensions, and method of fabrication of fluid power components limit the pressure and temperature at which a system operates. You have also learned of means of automatically controlling pressure in both hydraulic and pneumatic systems.

Most fluid power systems are provided with pressure gauges and thermometers for measuring and indicating the pressure and/or the temperature in the system. Additionally, various temperature and pressure switches are used to warn of an adverse pressure or temperature condition. Some switches will even shut the system off when an adverse condition occurs. These devices will be discussed in this chapter.

PRESSURE GAUGES

Many pressure-measuring instruments are called gauges. However, this section will be restricted to two mechanical instruments that contain elastic elements that respond to pressures found in fluid power systems—the Bourdon-tube and bellows gauges.

BOURDON TUBE GAUGES

The majority of pressure gauges in use have a Bourdon-tube as a measuring element. (The gauge is named for its inventor, Eugene Bourdon, a French engineer.) The Bourdon tube is a device that senses pressure and converts the pressure to displacement. Since the Bourdon-tube displacement is a function of the pressure applied, it may be mechanically amplified and indicated by a pointer. Thus, the pointer position indirectly indicates pressure.

The Bourdon-tube gauge is available in various tube shapes: curved or C-shaped, helical, and spiral. The size, shape, and material of the tube depend on the pressure range and the type of gauge desired. Low-pressure Bourdon tubes (pressures up to 2000 psi) are often made of phosphor bronze. High-pressure Bourdon tubes (pressures above 2000 psi) are made of stainless steel or other high-strength materials. High-pressure Bourdon tubes tend to have more circular cross sections than their lower-range counterparts, which tend to have oval cross sections. The Bourdon tube most commonly used is the C-shaped metal tube that is sealed at one end and open at the other (fig. 8-1).

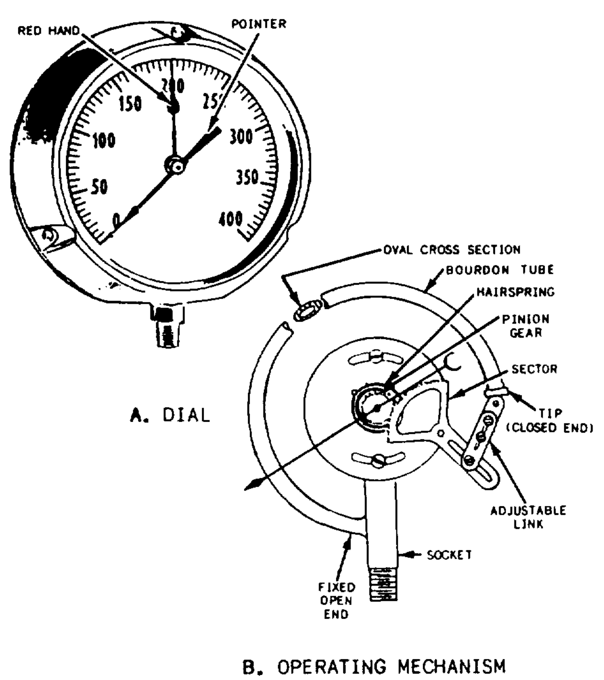


Figure 8-1.—Simplex Bourdon-tube pressure gauge.

C-shaped Bourdon Tube

The C-shaped Bourdon tube has a hollow, elliptical cross section. It is closed at one end and is connected to the fluid pressure at the other end. When pressure is applied, its cross section becomes more circular, causing the tube to straighten out, like a garden hose when the water is first turned on, until the force of the fluid pressure is balanced by the elastic resistance of the tube material. Since the open end of the tube is anchored in a fixed position, changes in pressure move the closed end. A pointer is attached to the closed end of the tube through a linkage arm and a gear and pinion assembly, which rotates the pointer around a graduated scale.

Bourdon-tube pressure gauges are often classified as simplex or duplex, depending upon whether they measure one pressure or two pressures. A simplex gauge has only one Bourdon tube and measures only one pressure. The pressure gauge shown in figure 8-1 is a simplex gauge. A red hand is available on some gauges. This hand is manually positioned at the maximum operating pressure of the system or portion of the system in which the gauge is installed.

When two Bourdon tubes are mounted in a single case, with each mechanism acting independently but with the two pointers mounted on a common dial, the assembly is called a duplex gauge. Figure 8-2 shows a duplex gauge with views of the dial and the operating mechanism. Note that each Bourdon tube has its own pressure connection and its own pointer. Duplex gauges are used to give a simultaneous indication of the pressure from two different locations. For example, it may be used to measure the inlet and outlet pressures of a strainer to obtain the differential pressure across it.

Differential pressure may also be measured with Bourdon-tube gauges. One kind of Bourdon-tube differential pressure gauge is shown in figure 8-3. This gauge has two Bourdon tubes but only one pointer. The Bourdon tubes are connected in such a way that they indicate the pressure difference, rather than either of two actual pressures.

As mentioned earlier, Bourdon-tube pressure gauges are used in many hydraulic systems. In this application they are usually referred to as hydraulic gauges. Bourdon-tube hydraulic gauges are not particularly different from other types of Bourdon-tube gauges in how they operate; however, they do sometimes have special design features because of the extremely high system pressures to which they may be exposed. For

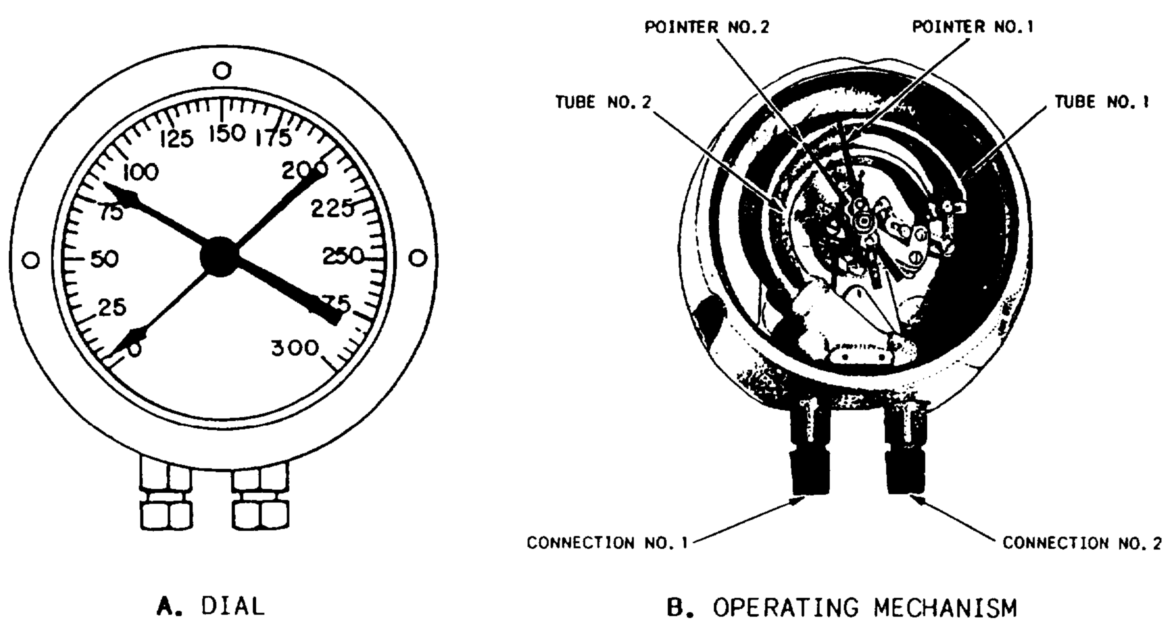


Figure 8-2.—Duplex Bourdon-tube pressure gauge.

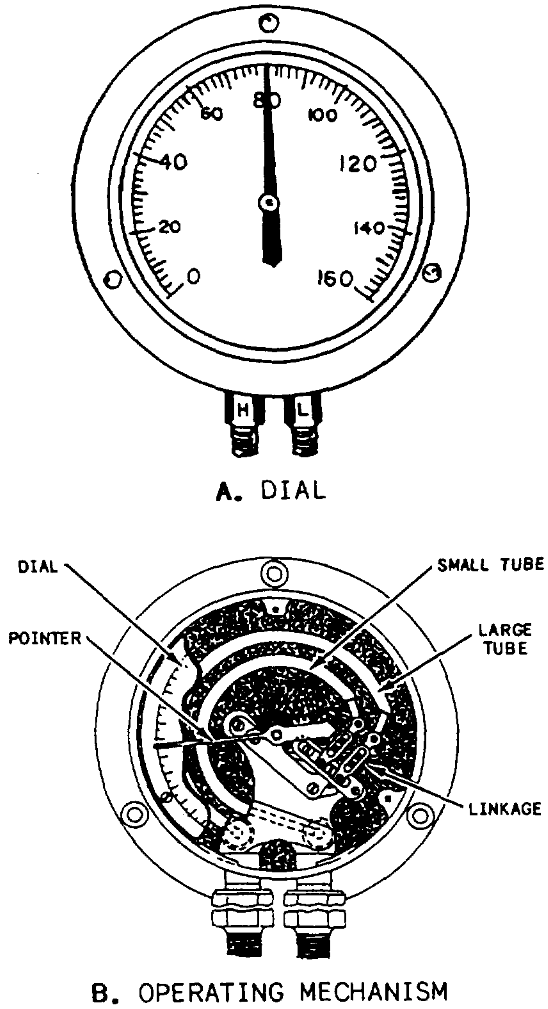


Figure 8-3.—Bourdon-tube differential pressure gauge.

example, some hydraulic gauges have a special type of spring-loaded linkage that is capable of taking overpressure and underpressure without damage to the movement and that keeps the pointer from slamming back to zero when the pressure is suddenly changed. A hydraulic gauge that does not have such a device must be protected by a suitable check valve. Some hydraulic gauges may also have special dials that indicate both the pressure (in psi) and the corresponding total force being applied, for example tons of force produced by a hydraulic press.

Spiral and Helical Bourdon Tubes

Spiral and helical Bourdon tubes (figs. 8-4 and 8-5) are made from tubing with a flattened cross

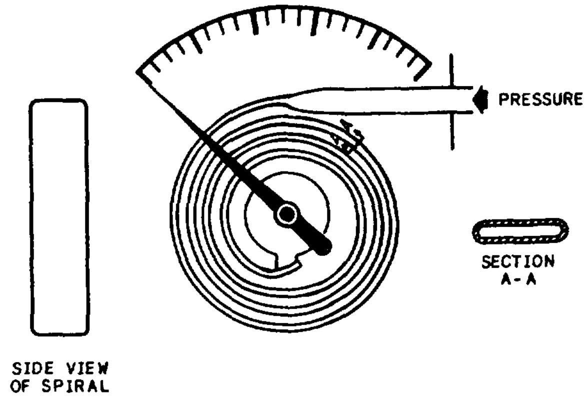


Figure 8-4.—Spiral Bourdon tube.

section. Both were designed to provide more travel of the tube tip, primarily for moving the recording pen of pressure recorders.

BELLOWS ELASTIC ELEMENTS

A bellows elastic element is a convoluted unit that expands and contracts axially with changes in pressure. The pressure to be measured can be applied to either the outside or the inside of the bellows; in practice, most bellows measuring

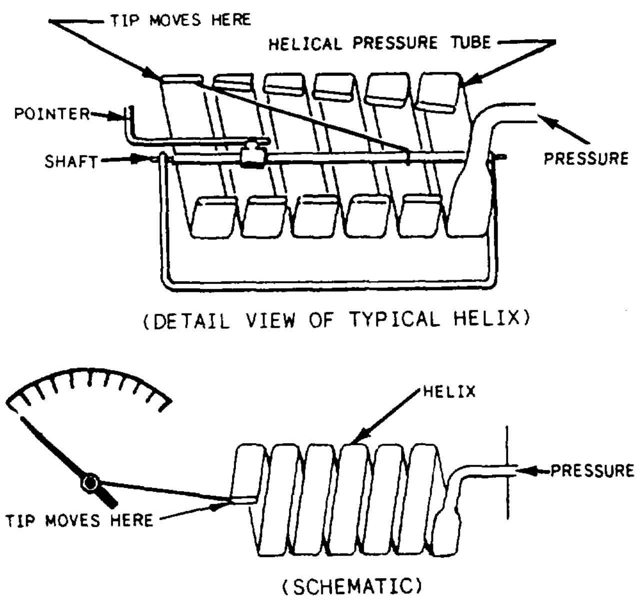


Figure 8-5.—Helical Bourdon tube.

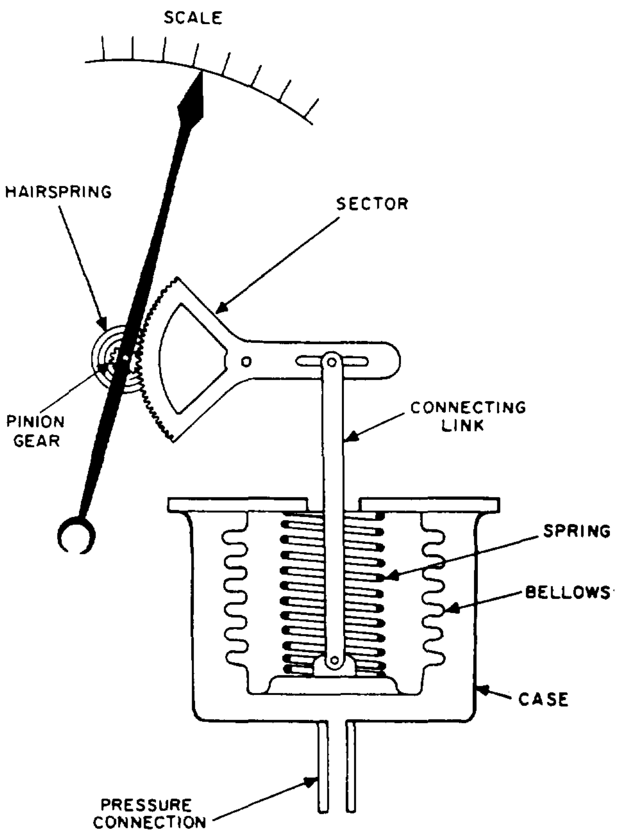


Figure 8-6.—Simple bellows gauge.

devices have the pressure applied to the outside of the bellows (fig. 8-6).

Simple Bellows Elements

Bellows elastic elements are made of brass, phosphor bronze, stainless steel, beryllium-copper, or other metal suitable for the intended service of the gauge. Motion of the element (bellows) is transmitted by suitable linkage and gears to a dial pointer. Most bellows gauges are spring-loaded—that is, a spring opposes the bellows and thus prevents full expansion of the bellows. Limiting the expansion of the bellows in this way protects the bellows and prolongs its life. Because of the elasticity in both the bellows and the spring in a spring-loaded bellows element, the relationship between the applied pressure and bellows movement is linear.

Dual Bellows Indicators

Another type of bellows element is the dual-bellows element. Figure 8-7 is a schematic diagram of this indicator. Dual-bellows element pressure indicators are used throughout the Navy as flow-measuring, level-indicating, or pressure-indicating devices.

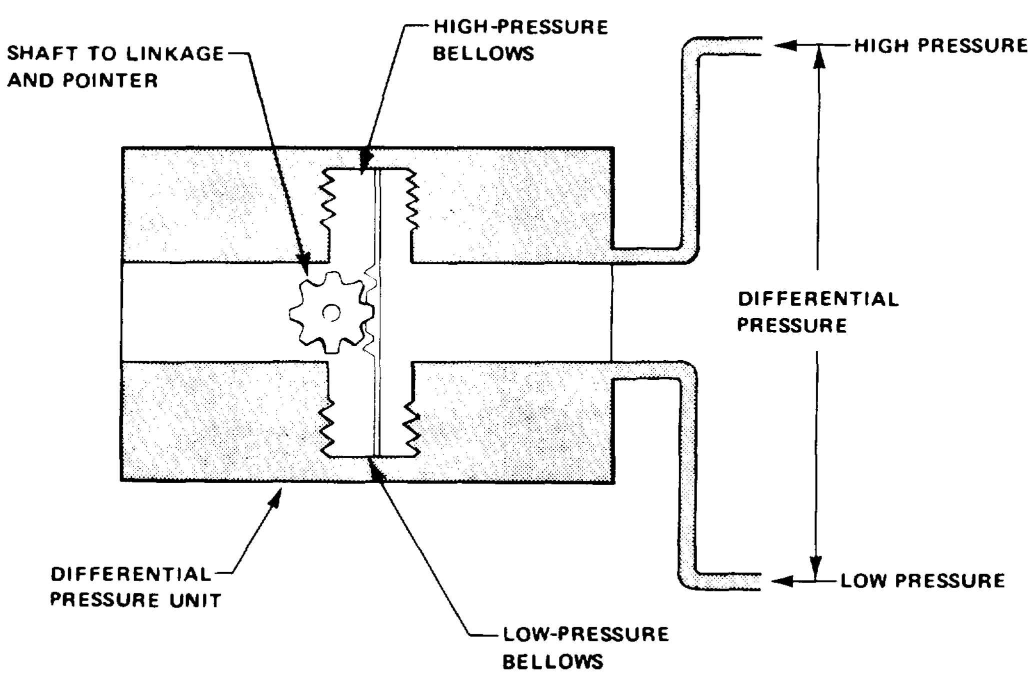


Figure 8-7.–Differential pressure sensor dual bellows.

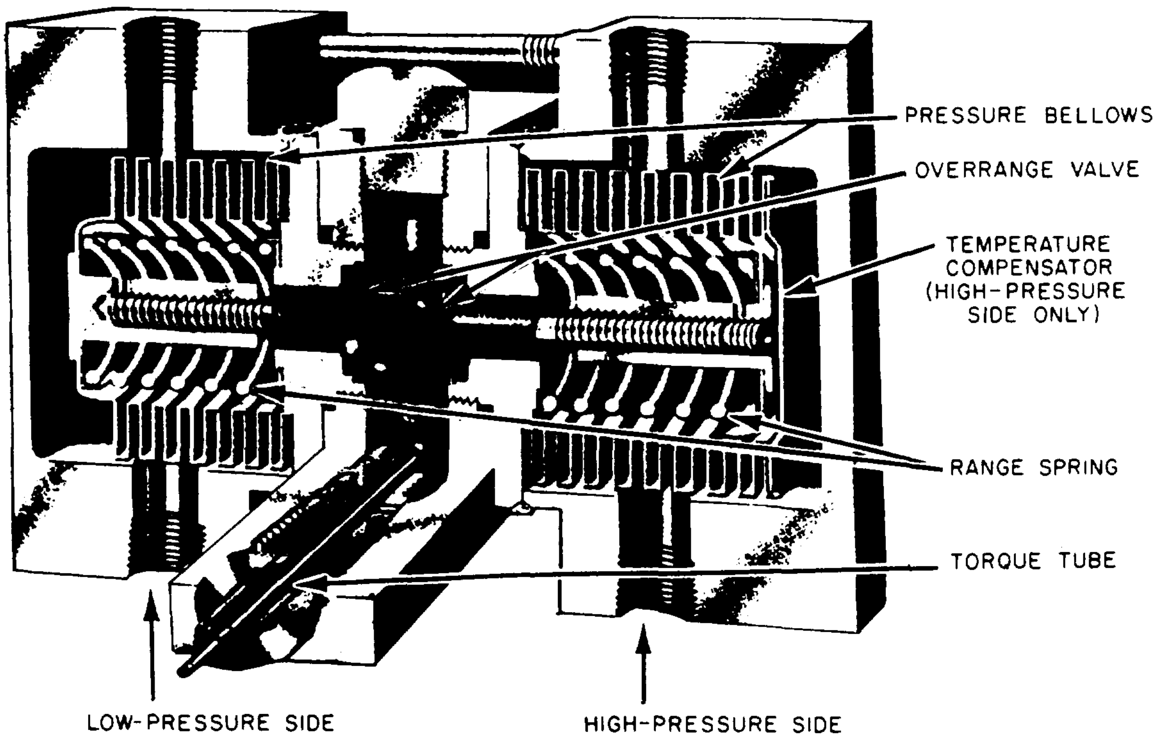


Figure 8-8.–Dual bellows assembly.

When in operation, the bellows will move in proportion to the difference in pressure applied across the bellows unit assembly. The linear motion of the bellows is picked up by a drive arm and transmitted as a rotary motion through a torque tube assembly (fig. 8-8). The indicating mechanism multiplies rotation of the torque tube through a gear and pinion to the indicating pointer.

Bellows elements are used in various applications where the pressure-sensitive device must be powerful enough to operate not only the indicating pointer but also some type of recording device.

PRESSURE SWITCHES

Often when a measured pressure reaches a certain maximum or minimum value, it is desirable to have an alarm sound a warning, a light to give a signal, or an auxiliary control system to energize or de-energize. A pressure switch is the device commonly used for this purpose.

One of the simplest pressure switches is the single-pole, single-throw, quick-acting type shown in figure 8-9. This switch is contained in a metal

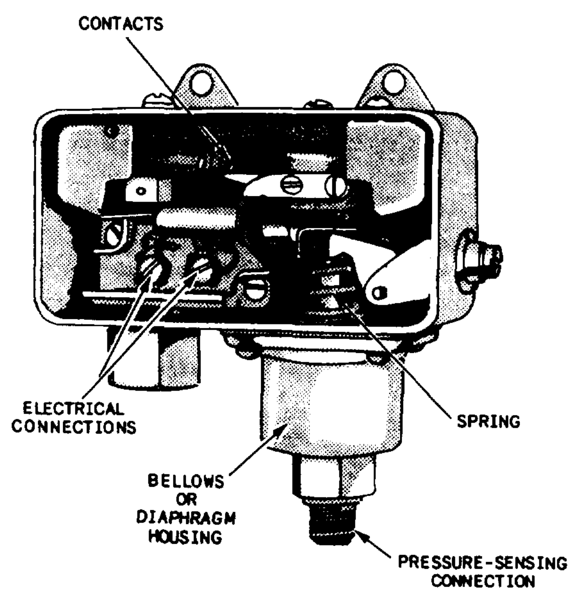


Figure 8-9.—Typical pressure switch.

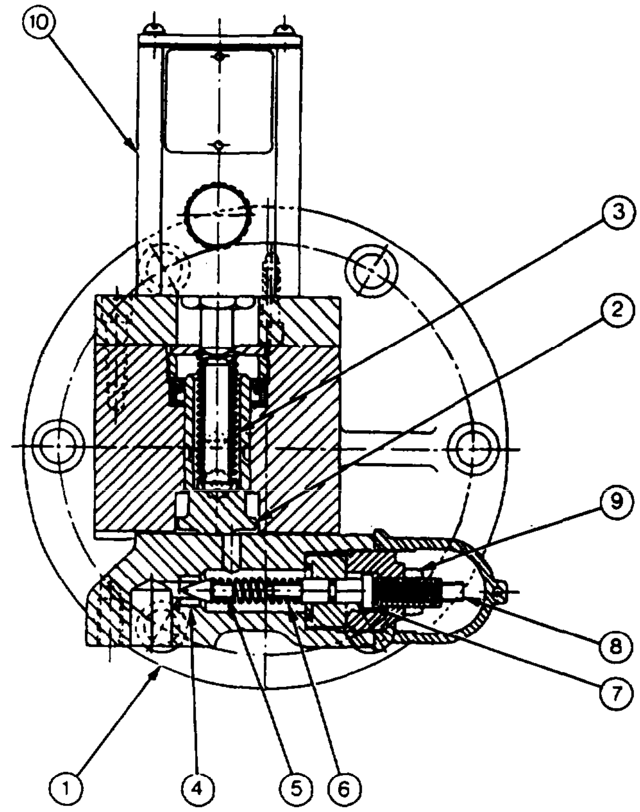
case that has a removable cover, an electrical connection, and a pressure-sensing connection. The switch contains a seamless metallic bellows located in its housing. Changes in the measured pressure causes the bellows to work against an adjustable spring. This spring determines the pressure required to actuate the switch. Through suitable linkage, the spring causes the contacts to open or close the electrical circuit automatically when the operating pressure falls below or rises above a specified value. A permanent magnet in the switch mechanism provides a positive snap on both the opening and closing of the contacts. The switch is constantly energized. However, it is the closing of the contacts that energizes the entire electrical circuit.

Another pressure switch is an electric-hydraulic assembly that is used for shutting off the pump's motor whenever the system pressure exceeds a pre-determined maximum value (fig. 8-10). The switch is mounted on the pump housing so that the former's low pressure ports drain directly into the pump housing.

This pressure switch principally consists of a flange-mounted hydraulic valve to which is fixed a normally closed electrical limit switch.

The valve consists of two hydraulically interconnected components, the pilot valve sub-assembly, which bolts on the bottom of the body (l), functions to sense system pressure continuously and initiates pressure switch action whenever this pressure exceeds the adjusted setting of the pilot adjustment. System pressure is directed into the bottom port and is applied against the exposed tip of the pilot piston (5). This piston is held on its seat by compression from the piston spring (6) which is dependent on the position of the adjusting screw (8). Whenever the pressure causes a force sufficiently large enough to raise the pilot piston from its seat, fluid flows through an interconnecting passage to the actuating piston (2) chamber. The accompanying fluid force raises the actuating piston against the force of spring 3 and causes depression of the extended switch plunger. This, in turn, disconnects the contained electrical switch, which may be connected into the pump motor's electric supply system.

Pressure switches come in many sizes and configurations depending on how they will be used.



1. **Body**
2. **Actuating Piston**
3. **Spring**
4. **Seat**
5. **Pilot Piston**
6. **Piston Spring**
7. **Plunger-Adjustment Screw**
8. **Adjusting Screw**
9. **Adjusting Screw Lock Nut**
10. **Limit Switch**

Figure 8-10.—Electric-hydraulic pressure switch.

TEMPERATURE-MEASURING INSTRUMENTS

Temperature is the degree of hotness or coldness of a substance measured on a definite scale. Temperature is measured when a measuring instrument, such as a thermometer, is brought into contact with the medium being measured.

All temperature-measuring instruments use some change in a material to indicate temperature. Some of the effects that are used to indicate temperature are changes in physical properties and altered physical dimensions. One of the more important physical properties used in temperature-measuring instruments is the change in the length of a material in the form of expansion and contraction.

Consider the uniform homogeneous bar illustrated in figure 8-11. If the bar has a given

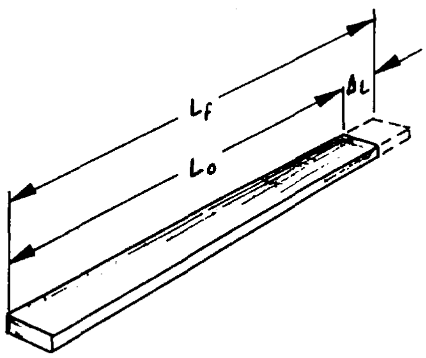


Figure 8-11.—Expansion of a bar.

length (L_o) at some temperature and is heated, it will expand (L_f). The amount of expansion (ΔL) is a function of the original length and the temperature increase. The amount a material changes in length with temperature is called the linear coefficient of expansion.

The linear coefficient of expansion for a material is a physical property of that material and describes its behavior with respect to temperature.

BIMETALLIC EXPANSION THERMOMETER

If two materials with different linear coefficients are bonded together, as the temperature changes their rate of expansion will be different. This will cause the entire assembly to bend in an arc as shown in figure 8-12.

When the temperature is raised, an arc is formed around the material with the smaller expansion coefficient. Since this assembly is formed by joining two dissimilar materials, it is known as a bimetallic element.

A modification of this bimetallic strip serves as the basis for one of the simplest and most commonly encountered temperature-measuring instruments, the bimetallic thermometer.

Figure 8-13 shows a bimetallic thermometer. In it, a bimetallic strip is wound in the form of a long helix. One end of the helix is held rigid. As the temperature varies, the helix tries to wind or unwind. This causes the free end to rotate. The

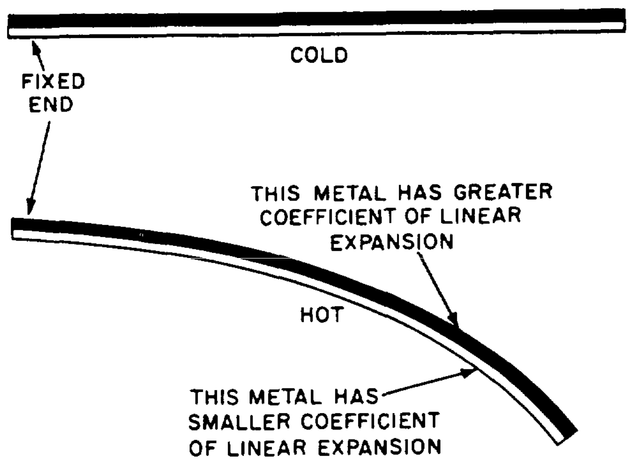


Figure 8-12.—Effect of unequal expansion of a bimetallic strip.

free end is connected to a pointer. The pointer actually indicates angular rotation of the helix; however, since the rotation is linear and a function of temperature, the scale is marked in units of temperature.

DISTANT-READING THERMOMETERS

Distant-reading dial thermometers are used when the indicating portion of the instrument must be placed at a distance from where the temperature is being measured. The distant-reading thermometer has a long capillary, some

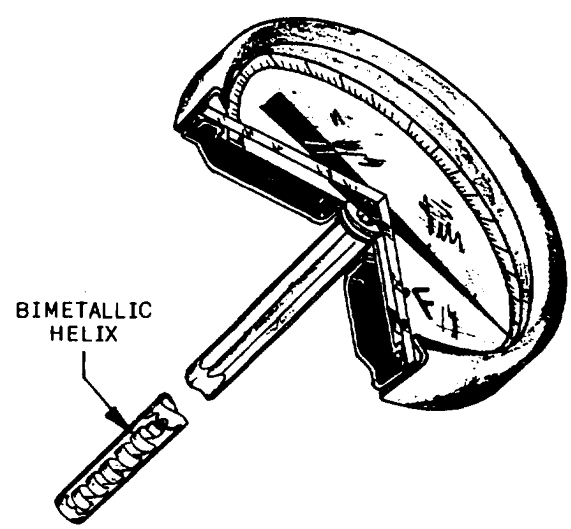


Figure 8-13.—Bimetallic thermometer.

as long as 125 feet, which separates the sensing bulb from the Bourdon tube and dial (fig. 8-14).

There are three basic types of distant-reading thermometers: the liquid filled, the gas filled, and the combination liquid-vapor filled. The thermometers are filled with fluid (liquid or gas) at some temperature and sealed. Almost the entire volume of the fluid is in the sensing bulb.

As the temperature of the bulb changes, the volume of the fluid tries to change. Since the volume of the thermometer (sensing bulb, capillary, and Bourdon tube) is constant, a pressure change occurs within the thermometer. This pressure change causes the Bourdon tube to straighten out (with an increase in pressure), working a system of levers and gears, which causes the thermometer pointer to move over the dial and register temperature.

TEMPERATURE SWITCHES

Temperature switches operate from temperature changes occurring in an enclosure, or in the air surrounding the temperature-sensing element. The operation of the temperature switch is similar to the operation of the pressure switch shown in figure 8-9; both switches are operated by changes in pressure. The temperature element is arranged so a change in temperature causes a change in the internal pressure of a sealed-gas or air-filled bulb or helix, which is connected to the actuating device by a small tube or pipe. Figure 8-15 shows a temperature switch and two types of sensing elements.

A temperature change causes a change in the volume of the sealed-in gas, which causes movement of a bellows. The movement is transmitted by a plunger to the switch arm. The moving contact is on the arm. A fixed contact may be arranged so the switch will open or close on a temperature rise. This allows the switch contacts to be arranged to close when the temperature drops to a predetermined value and to open when the temperature rises to the desired value. The reverse action can be obtained by a change in the contact positions.

GAUGE SNUBBERS

The irregularity of impulses applied to the fluid power system by some pumps or air compressors causes the gauge pointer to oscillate violently. This makes reading of the gauge not only difficult but often impossible. Pressure oscillations and other sudden pressure changes existing in fluid power systems will also affect the delicate internal mechanism of gauges and cause either damage to or complete destruction of the

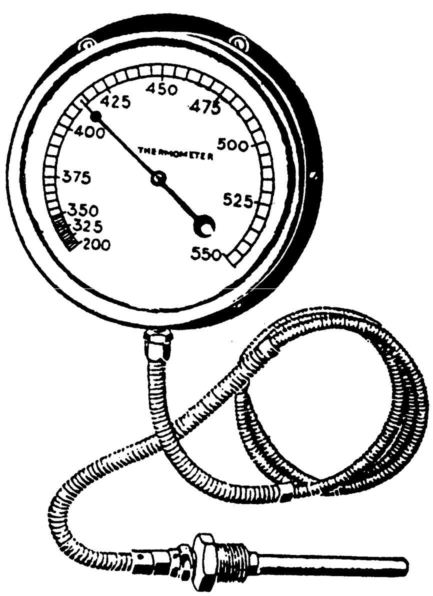


Figure 8-14.—Distant-reading, Bourdon-tube thermometers.

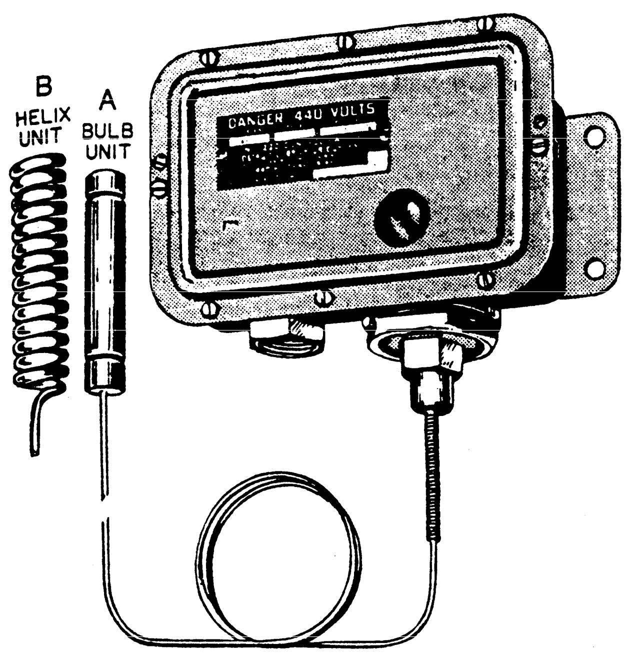


Figure 8-15.—Temperature switch with two types of sensing elements. A. Bulb unit. B. Helix unit.

gauge. A pressure gauge snubber is therefore installed in the line that leads to the pressure gauge.

The purpose of the snubber is to dampen the oscillations and thus provide a steady reading and protection for the gauge. The basic components of a snubber are the housing, fitting assembly with a fixed orifice diameter, and a pin and plunger assembly (fig. 8-16). The snubbing action is obtained by metering fluid through the snubber. The fitting assembly orifice restricts the amount of fluid that flows to the gauge, thereby snubbing the force of a pressure surge. The pin is pushed and pulled through the orifice of the fitting assembly by the plunger, keeping it clean and at a uniform size.

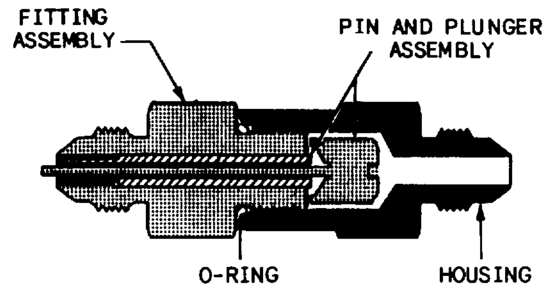


Figure 8-16.—Pressure gauge snubber.